8 NOVEMBER 1980 (FOUO 17/80) 1 OF 1

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USSR Report

ECONOMIC AFFAIRS

(FOUO 17/80)

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USSR REPORT

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CONTENTS

 [III - USSR - 3 FOUO]

INVESTMENT, PRICES, BUDGET AND FINANCE

UNIT COST OF FIXED CAPITAL ANALYZED

Moscow VOPROSY EKONOMIKI in Russian No 8, Aug 80 pp 121-132

[Article by V. Fal'tsman: "The Capacity Equivalent of Fixed Capital"]

[Text] In an article entitled "Ways of Improving the Effectiveness of Capital Investment" Academician T. Khachaturov points out the reasons for the growth of the output-capital ratio and the capital-output ratio for output in the sectors of the national economy: deterioration in the quality of raw materials and the increasing cost of extraction, shifts in the siting of industry in new regions, changes in the prices of equipment and machinery, increasing outlays for environmental protection and so forth.[1] Solving these questions is an important condition for improving work efficiency and the quality of work--tasks whose urgency was stressed at the CPSU Central Committee June (1980) plenum.

In our opinion, of special interest in this direction is analysis of the dynamics involved in the capacity equivalent of fixed capital. The capacity equivalent is characterized by the equivalence of fixed capital invested at different periods of time, from the viewpoint of production capacities. It can be measured with the aid of an index that is calculated as the particular derived from dividing the commissioning of a production capacity, expressed in physical units, into the fixed capital inverted, and it determines the projected yield from fixed capital expressed in physical terms for individual production facilities. The magnitude of the capacity equivalent for the commissioning of capital is inversely proportional to the unit cost of production capacities.

Statistics on the commissioning of capacities and fixed capital make it possible to establish the capacity equivalent for many production facilities and to calculate indices for the dynamics of each such index and a mean index weighted according to the value of invested capital. Since the physical measure for a production capacity can be structurally inhomogeneous (for example, finished rolled metal includes a large number of brands, shapes and dimensions), studies of the dynamics of the capacity equivalent must be conducted for products that are homogeneous in terms of their structure, or a special correction must be introduced that takes into account the effect of structure and the quality of output.

Calculations made for 30 checkpoint items for capacities distinguished by a relatively homogeneous structure and output quality have shown that the unit cost of commissioned capacities increased during the Ninth Five-Year Plan by an average of at least 5-6 percent annually while the value of invested capital increased by about 7 percent, that is, almost all the increase in the investment of fixed capital went to offset the reduced capacity equivalent. As a result of the increase in the average value of production capacities during the Ninth Five-Year Plan, even though the total volume of capital investment throughout the entire national economy was met, for many sectors, targets for the commissioning of production capacities were not.[2]

If all additional annual growth of capital is spent on offsetting the reduction in the capacity equivalent, the commissioning of production capacities remains the same year after year. Then, however, conditions are created for reducing the rates of economic growth because there is an increase in the buildup of production capacities and in the volume of output produced, which serves as the basis for calculating growth rates.

Suppose that at the start of a period 80 units of production capacities are available. During the year another seven units of capacities are commissioned. For simplification we exclude withdrawals of capacities and we also assume that existing and commissioned capacities are at 100-percent utilization; production growth rates are then 108.7 percent [100(80 + 7): 80]. If in each subsequent year the commissioning of production capacities remains unchanged at the same level (seven units), then after three years growth rates will be 107.4 percent [100 (80 + 21):(80 + 14)], that is, they will fall.

It can be seen from Table 1 that the drop in the capacity equivalent also continued in the Tenth Five-Year Plan. For 12 of the 15 items on the list its magnitude decreased in the period 1976-1977 relative to the level of the Ninth Five-Year Plan, and the mean weighted index for change in the capacity equivalent was 0.9, that is, each year the capacity equivalent for the investment of fixed capital fell about 5 percent. At the same time the annual investment of capital also increased 5 percent.

It can be assumed that through the increase in the share of imported equipment and the rapid rises in the prices for it, during the Tenth Five-Year Plan the fall in the capacity equivalent for invested capital will take place more rapidly than during the Tenth Five-Year Plan. Moreover, in the current five-year plan, planned rates for annual growth of capital investments has been reduced to 5 percent against the 6-7 percent of the preceding five-year plan. Under these conditions, average annual rates for the fall in the capacity equivalent will reach 6-7 percent and will exceed growth rates for capital investments and fixed capital.

As a result of the price costs for production capacities outstripping the growth rate for the investment of fixed capital, an absolute drop is taking place in the commissioning of production capacities. In order to show the effect of the relationship between fixed capital investment and price increases for capacities on the rate of economic growth, let us assume, as in the earlier example, that at the start of a period, capacities are available for the production of 80 units of output. Let us say that in the third year the rates at which capacity costs are increasing exceed growth rates for the investment of fixed capital while in previous years they coincided. As a result of this there is an absolute

Table 1. Dynamics of Capacity Equivalent for Investment of Fixed Capital

Production capacities	Unit of measurement used for capacity equivalent	Capacity equivalent		Index
		1971-1975	1976-1977	
Power stations	Thousands of kW / millions of rubles	6.18	5.35	0.87
Electricity networks, 35 kW and higher	kilometers / millions of rubles	39.73	44.18	1.11
Coal extraction	millions of tons / millions of rubles	0.025	0.016	0.64
Iron ore extraction	thousands of tons / millions of rubles	48.91	68.4	1.4
Steel pipes	Do.	2.98	2.53	0.85
Mineral fertilizers	thousands of stand. units / millions of rubles	5.94	5.82	0.98
Soda ash	thousands of tons / millions of rubles	3.89	1.96	0.50
Chemical fibers	Do.	0.31	0.21	0.68
Synthetic resins and plastics	Do.	1.58	1.34	0.85
Pulp and paper industry	Do.	1.36	0.66	0.48
Cement	Do.	19.07	12.03	0.64
Tractors	units / millions of rubles	49.0	73.0	1.49
Metal-cutting lathes	Do.	38.0	19.0	0.50
Meat	tons per shift / millions of rubles	3.02	2.43	0.80
Whole-milk products	Do.	12.08	9.75	0.81
Total	-	-	-	0.90

drop in capacities commissioned, and as a result, a further drop in the rate of output growth:

	Year 1	Year 2	Year 3
Unit cost of commissioned capacity (conventional units)	20	21.2	23.1
Growth rate (percent)	106	106	109
Fixed capital investment (conventional units)	140	148.8	154.3
Growth rate (percent)	106	106	104
Commissioning of capacities (conventional units)	7	7	7
Output (conventional units)	87	94	100.7
Growth rates (percent)	108.7	108.0	107.1

The statistics for the commissioning of capacities indicate that the average annual volumes for the commissioning of capacities during three years of the Tenth Five-Year Plan were for many items lower than during the preceding five-year period (see Table 2). An absolute fall in the commissioning of capacities is being observed in the following: coal and iron ore extraction; production of cast iron, rolled metal, mineral fertilizers, soda ash, chemical fibers and threads, transformers, metal-cutting lathes, paper, cement, precast ferroconcrete; the setting up of looms and the production of leather footwear, meat, whole-milk products and many other products. In the aggregate, this drop has taken place for 38 of the 54 most important product items, while during the Ninth Five-Year Plan a trend toward an absolute increase in commissioned capacities predominated.[3] It is characteristic that falling rates for the growth of capacities commissioned are also observed for such kinds of output that are distinguished by a relative homogeneity structurally and qualitatively (for example, electric power and cast iron), as it is also for output whose rating and volume is measured in conventional units (mineral fertilizers) and in units of power (transformers).

Thus, at the present stage a situation has developed in which the fall in the capacity equivalent for invested capital is occurring so rapidly that it cannot be made up by the growth in the volumes of capital investments, as a result of which a process of falling commissioning of capacities has been initiated.

Even given stabilization of the average annual commissioning of capacities at a constant level, production growth rates will gradually fall. And the absolute fall in capacities commissioned promotes a more rapid drop in production growth rates. As a result (given the condition of no change in the yield from existing fixed capital and capacities), after two or three years the preconditions come about for a drop in economic growth rates and additional constraints on the sources of capital investment growth, and then for a new drop in capacities. Since production capacities and fixed capital are formed by construction and machine building, potential sources for increasing the capacity equivalent are found primarily in these sectors.

Calculations made on the basis of listings of production areas and fixed capital for 1960 and 1972 show that the cost of one square meter of production area increased at an annual rate of 5-6 percent, that is, at almost the same rate by

Table 2. Dynamics in Commissioning of the Most Important Production Capacities

	Unit of measurement	Average annual commissioning of production capacities			Index for change in average annual commissioning of capacities		
		1966-1970	1971-1975	1976-1978	1971-1975 v. 1966-1970	1976-1978 v. 1966-1970	1976-1978 v. 1971-1975
1	2	3	4	5	6	7	8
Power stations	millions of kW	10.9	11.6	10.1	1.06	0.93	0.87
Coal extraction	millions of tons	19.0	22.8	18.6	1.20	0.98	0.82
Iron ore extraction	Do.	24.1	26.3	24.8	1.09	1.03	0.94
Production of cast iron	Do.	1.9	2.6	1.7	1.37	0.89	0.65
Production of steel	Do.	3.6	2.2	3.4	0.61	0.94	1.54
Production of rolled metal	Do.	2.9	2.4	2.2	0.83	0.76	0.92
Production of steel pipes	thousands of tons	494.0	477.0	493.7	0.97	1.00	1.03
Production of mineral fertilizers	mill. t. stand. un	6.6	7.6	4.5	1.15	0.68	0.59
Production of sulfuric acid	millions of tons	0.8	1.7	1.9	2.12	2.37	1.12
Production of soda ash	thousands of tons	244.0	208.0	118.3	0.85	0.48	0.57
Production of chemical fibers and threads	Do.	30.2	69.9	49.4	2.31	1.64	0.71
Production of automobile tires	millions	1.7	2.6	2.9	1.53	1.71	1.12
Production of power transformers	millions of kVA	5.6	4.1	1.7	0.73	0.30	0.41
Production of metal-cutting lathes	thousands of units	4.3	5.1	2.9	1.19	0.67	0.57
Production of tractors	Do.	24.2	15.9	29.1	0.66	1.20	1.83
Production of paper	thousands of tons	100.0	102.0	45.0	1.02	0.45	0.44
Production of cement	millions of tons	3.5	4.1	3.1	1.17	0.89	0.76
Production of precast ferro-concrete structures and parts	millions of cubic meters	4.8	5.9	4.9	1.23	1.02	0.83
Spinning spindles set up	millions	0.6	0.4	0.4	0.67	0.67	1.00
Looms set up	thousands	9.5	8.3	3.4	0.87	0.36	0.41
Production of leather footwear	millions of pairs	29.8	13.5	4.1	0.45	0.14	0.30
Production of meat	thousands of tons per shift	0.4	0.8	0.7	2.00	1.75	0.87
Production of whole-milk products	thousands of tons per shift	2.5	2.5	1.9	1.00	0.76	0.76
Railroad lines constructed	thousands of km.	0.8	0.7	0.7	0.87	0.87	1.00

which the capacity equivalent dropped for all fixed capital. Hence it follows that the contribution from each of the two capital-forming sectors--construction and machine building--in the fall in the capacity equivalent is about the same. The rates at which the capacity equivalent for all fixed capital and for their active parts is falling are also equal. This is confirmed by the dynamics of the technologic structure of capital investments. If the value of the active or passive component had grown rapidly it would have caused a corresponding change in their ratio. In the meantime, the share of equipment in production capital investments during the period 1966-1975 remained virtually unchanged while the capacity equivalent dropped substantially.

The experience of a number of the industrially developed countries (the United States, Great Britain and others) shows that the long-term trend is toward increasing cost per unit of construction output. In machine building, however, there are major opportunities for reducing production costs per unit of utility.[4] In the USSR this trend is being deepened by the fact that the pioneer-type opening up of new territories is being conducted in difficult climatic conditions and on massive scales. In the opinion of specialists, the most important thing to be taken into account in the future with planning improvements and the utilization of local and new, progressive construction materials, is stabilization of the square-meter cost of production areas, or even a slight cost reduction. Since the potential of construction in solving the capacity equivalent problem is limited, a study of the possibilities of machine building is of special interest. Increased costs for machine building output per unit of capacity commissioned can be caused by two circumstances--increasing equipment costs per unit of productivity (capacity), and an increase in the inventory of equipment that outstrips capacities and output--equipment which does not directly increase output but creates merely favorable conditions for expanding production volumes (equipment for the production infrastructure, environmental protection, offsetting deteriorating conditions for ore extraction, means of mechanization and automation).

The USSR Central Statistical Administration has conducted one-off sampling investigations of the relationships between wholesale prices and the productivity of new (acquired during 1975-1977) and base (replacement) equipment for machine building enterprises. Indexes were established for changes in wholesale prices (J_1) and productivity (J_2) for new and replacement machines and equipment, and the calculation was made of the coefficient for the relationship of wholesale prices for new and base (replacement) equipment, as $J=J_1:J_2$. An increase in the cost of a unit of capacity for equipment takes place when $J>1$, that is, when the wholesale price has increased more rapidly than the productivity of the equipment. The most representative results were those from a study of four machine building industries:

	Number of brands studied	Those with $J>1$	$J_{av.}$
Ministry of the Electrical Equipment Industry	66	16	0.9
Ministry of Chemical and Petroleum Machine Building	74	37	0.9
Ministry of Machine Building	37	15	1.0
Ministry of Machine Building for Animal Husbandry and Fodder Production	16	8	0.7

From the data cited it follows that although increasing cost per unit of capacity is also being observed for many brands of equipment, the number did not exceed 50 percent in any of the four ministries studied. At the same time, for each ministry, the average relationship between wholesale prices for new and base (replacement) equipment (J_{av}) was less than unity, which indicates a reduction in the cost of equipment. In our view, this is not typical for all machine building since the study does not cover many of its branches and in terms of the kinds of equipment studied relates predominantly to large-series production. Accordingly, it is advisable to regard the data cited jointly with results from other studies.

Since the volumes of output for power and electrotechnical equipment is calculated both in units of capacity and in value terms (in constant prices) it is possible to make a direct measurement of the dynamics of unit cost for their capacities. According to our calculations, during the Eighth and Ninth Five-Year Plans the average unit cost for the capacity of power equipment (boilers and turbines of all kinds) increased 25 percent, while the cost per kilowatt of capacity for electrotechnical equipment increased 27 percent.[5] Similar calculations for 1976-1978 have shown that growth rates in the increasing unit cost for the capacity of this equipment during the Tenth Five-Year Plan has not only not fallen but has even increased.

Judging from the dynamics for productivity as calculated by the Experimental Scientific Research Institute of Metal-Cutting Machine tools and the average price per machine tool fell during the Ninth Five-Year Plan by about 5 percent. However, studies conducted by the State Committee on Prices show that productivity growth for machine tools at 1 percent causes a rise in the upper limit of prices to 14-15 percent.[6]

The unit cost for the capacity of metallurgical equipment is increasing. Thus, according to the figures of V. Shtanskiy, the cost of one ton of technologic equipment for the "1700" strip mill for hot-rolled sheet, commissioned in 1968, was 35 percent higher than for a similar mill installed in 1960, while a "2000" strip mill manufactured in 1971-1973 was 30 percent more expensive than a similar mill commissioned in 1968-1969. The cost of equipment for 100-ton-capacity converters increased by a factor of almost 1.5 during the period 1965-1969, while during the period 1971-1973 the cost of a 300-ton-capacity converter increased 12 percent.[7] A trend toward increased weight per unit of productivity is being observed in the development of the structures for rolling mills. In terms of weight, new rod mills are three times heavier than old mills, but their productivity is only 1.5 times higher. The cost of one ton of rolling equipment is also rising. Even in the period 1972-1975 the cost of one ton of rolling equipment in constant prices increased 8 percent. The replacement costs of, for example, light-section mills--the "280" tandem mill, the "250" continuous rolling mill, and the "250" continuous high-speed rolling mill--are increasing in ratios of 1:6:10 while productivity ratios are 1:3:4 respectively.[8]

According to L. Suvorina's calculations, the unit cost of productivity for earthmoving and earth-leveling equipment, means of transportation and tractors is increasing. Average annual rates for this increase for five-year plans (as percentages) are as follows:[9]

	Eighth Five-Year Plan	Ninth Five-Year Plan
Mechanical shovels	0.9	0.5
Bulldozers	4.6	2.2
Trucks	6.5	1.1
Mainline diesel locomotives	4.6	0.7
Caterpillar tractors	9.2	1.6
Wheeled tractors	3.4	4.5

Although not complete enough to discern general patterns in the change in the unit cost for the capacity of Soviet-made equipment, the figures nevertheless make it possible to state that the unit cost of productivity for many kinds of equipment is on the increase.

A generalized assessment of increases in the unit cost of capacity for both Soviet-made and imported equipment can be made by comparing the dynamics for energy consumption and the value of the active part of fixed capital (the idea of such calculations was first mooted by Academician T. Khachaturov).[10] Let us assume that the total productivity for the machinery inventory is measured by the amount of energy used, including electric power. A rise in the growth rates for the value of the active part of fixed capital in comparable prices above the growth rates for energy requirements, including demand for electric power, characterized growth rates for the increasing unit cost of productivity (capacity) of equipment. This kind of evaluation can be overstated if within the period analyzed there is deterioration in equipment utilization or the running times for engines.

Within the industry the growth indexes for the indicators examined were as follows:[11]

	1966-1975	1976-1977
Active part of fixed capital	2.30	1.17
Energy demand	1.90	1.09
Demand for electric power	1.90	1.09
Unit cost for productivity of equipment	1.21	1.07

Using the index for the unit cost of productivity for equipment it it possible to calculate the maximum possible average annual rates of increase for it. During 1966-1970 it was about 2 percent; in 1971-1975 it was 3 percent; and in 1976-1977 it increased to 3.5 percent; and the average for the Tenth Five-Year Plan will evidently be about 3 percent. Calculations show that the increasing unit cost for the productivity of equipment seen in recent years has been caused mainly by an increase in the share of imported equipment and the rising prices for imports.

If capacity equivalent for the investment of the active part of fixed capital falls annually by 5-6 percent while the cost of equipment increases by 2-3 percent, then the increasing unit cost for productivity can explain no more than half of this fall. The other causes are outlays on means of mechanization to replace manual labor, the automation of production processes, the development of the production infrastructure, environmental protection, offsetting deteriorating natural conditions and so forth, which in many sectors and national economic complexes are increasing more rapidly than output. As a result, they also exert an effect on the fall in the capacity equivalent for invested capital.

For example, studies on the dynamics in the delivery of equipment to sectors of the fuel-and-energy complex indicate that 15 percent of the extra demand is for equipment that offsets deteriorating natural conditions (outlays on restructuring sites associated with the switchover from gusher to pumping extraction of petroleum, expanding recovery from strata with pressure maintenance and so forth), 11 percent for the purchase of means of transportation, equipment for electricity and heating networks, and means of communication, that is, for the development of the production infrastructure, primarily in new regions, 11 percent for mechanization, primarily in coal mines, and 8 percent for purchases of equipment for automating production processes and control equipment for the branches of the complex.

When investigating the dynamics of the capacity equivalent, the role of equipment acquired that does not directly promote output volume growth should not be exaggerated. Until recently this kind of exaggeration formed the basis of the theoretical concept of the development of the output-capital ratio in production. In the economic literature, the viewpoint predominated that the effect of technologic progress on the output-capital ratio is seen in different ways at the two stages of machine production. At the first stage, when as the result of technologic progress there is the initial replacement of manual labor, the output-capital ratio rises substantially; at the second stage the predominant role is played by the replacement of less productive equipment with more productive equipment, and live labor is saved not only by the direct replacement of manual labor with machines but also indirectly, and conditions are created for reducing the output-capital ratio.[12]

Analysis shows that during the seventies not even 50 percent of the changes in the capital-output ratio and return on investment could be explained by the mechanization of manual labor. For sectors such as machine building and ferrous metallurgy, labor mechanization had only an insignificant effect on the return from investments On the whole, although it exerts a marked effect on the output-capital ratio, labor mechanization is not the key factor explaining its dynamics. Research that has been conducted makes it possible to provide a certain approximate assessment of the distribution in the drop in the capacity equivalent for investments among three factors—the increase in per square meter cost of commissioned areas, the increase in the unit cost of equipment productivity, and extra outlays on building up the inventory of equipment not directly connected with expanding output volumes. If we take the entire drop in the capacity equivalent in percentage terms, about 50 percent is attributable to the construction factor and about 25 percent each to each of the machine building factors mentioned. Together with the sector structure of output, the structure of technologic methods for the production of output, the technologic structure of capital investments and repeated calculation for determining output volumes, these factors form the dynamics of the increasing capital-output ratio and yield from capital.

An increase in outlays to build up the inventory of equipment not directly connected with increasing output is also being observed in other developed countries, and is evidently unavoidable in increasing scales. Thus, according to M. Shukhgalter, in the United States the share of multisector equipment--computers, instruments, and transport lifting equipment--is increasing in the output of machine building. Capital investment in environmental protection is growing rapidly. In ferrous metallurgy it has already reached 15.7 percent, in power engineering 10.4 percent and in the petrochemical industry 8.2 percent. Along with these factors, unfavorable from the viewpoint of the capacity equivalent, in the processing industry in the United States the percentage of capacities per 1 percent of the growth of capital embodied in operating equipment and production equipment is constantly rising. In the period 1950-1957 it was 1.24; in 1957-1966 it was 2.04, and in 1966-1972 it was 2.13.

Like outlays on acquiring multisector equipment, it seems that the growing cost per unit of construction output is inevitable. Accordingly, possibilities for altering the negative dynamics of the capacity equivalent should be sought primarily in a relative price reduction for equipment. We shall analyze in more detail the reasons for the growth in per unit cost of machine productivity and the factors capable of causing a drop in this growth.

A number of economists consider that the increasing cost per unit of productivity for equipment is primarily the result of unjustified price increases for equipment. Data from a one-time study by the USSR Central Statistical Administration, however, have shown that profitability for new equipment, calculated against the production cost for those brands for which there has been an increase in the per unit cost for capacity, was on average lower than profitability for the total output of the appropriate machine tool ministry, including total new output. If the increase in the prices for equipment had been the result of systematic error in price forming it would have caused a rapid and general rise in the level of profitability for the output of the machine tool industries, as determined against production costs. The statistics do not confirm that such growth has occurred. According to figures from the USSR State Committee on Prices, during 1968-1973 wholesale prices for machine tool building output were reduced by more than 14 billion rubles--about 10 percent of the volume of investment equipment deliveries.[14] Here, the level of average prices for machines became higher because of the increase in the specific share of more complex and high quality equipment with good technical-economic parameters.

Finally, there are also cases of unjustified price increases for individual kinds of equipment, in particular when it is delivered with the price set by comparison with similar equipment or on a one-time basis. Figures have been published in the economics literature according to which the cost of metallurgical equipment, for half of which there are no price handbooks, and agricultural and other equipment, is rising. The reason for the increase in the prices for Soviet-made machines, calculated per unit of productivity, also lies in the fact that improvements in technical-economic indicators are not limited only to increasing unit capacity but also include other utility components. According to figures from A. Koshuta and L. Rozenova, only about 30 percent of the total utility of new mill equipment is assigned to labor productivity.[15] A one-time study by the USSR Central Statistical Administration showed that in the total for the general, calculated economic effect, the effect of increased productivity for equipment is about 30 percent for the Ministry of the Electrical Equipment Industry, Ministry of Machine Building and Ministry of Machine Building for Animal Husbandry and Fodder Production, while for the Ministry of Chemical and Petroleum Machine

Building it is only 23 percent. For models with increasing cost per unit of capacity ($J>1$) the share of equipment productivity in the total effect taken as an average for the four ministries equals the same share for the entire aggregate of brands studied, while for the Ministry of the Electrical Equipment Industry and the Ministry of Machine Building for Animal Husbandry and Fodder Production it even exceeds it. Hence it follows that in a number of machine building sectors technical progress is aimed not so much at improving the productivity of equipment, labor productivity, and saving equipment and labor, as at achieving other socio-economic goals.

About two-thirds of the utility goes to saving current operating costs--reducing the expenditure of fuel, energy and raw materials, and ultimately production costs. The effect from increasing the service life of equipment is no greater than 5 percent, while the share of outlays to improve working conditions in 1-2 percent of the total utility. These figures are average figures for the brands of machines studied and there are substantial variations for individual brands.

Thus, in some sectors of modern machine building, technical progress is aimed not so much at saving live labor by improving the productivity of the machines as at cutting back operating costs. In these conditions, the increase observed in the cost per unit of productivity for equipment is partially justified by the saving on current outlays. Here, calculated per unit of utility, the price of machines can fall even when it is rising per unit of productivity.

From the above it follows that Soviet machine building does not have opportunities to reduce the cost per unit of capacity for equipment, which is an essential precondition for switching to a capital-saving type of economic development. The potential reserves for reducing the cost of equipment are: reducing the amount of metal used in machine building output, improving the organization of machine building production, reducing labor intensiveness on assembling machines through mechanization and automation, optimizing the characteristics of equipment produced and finding replacements for imported machines. Let us deal in more detail with each of these avenues.

According to specialist evaluations, domestic machine building has at its disposal great opportunities for reducing the amount of metal used in production. However, this does not always lead to a reduction in the cost of machines since the reduced use of metal is achieved by using more expensive substitute materials. For example, sized metal is about 1.3 times more expensive than hot-rolled metal, and sheet metal about 1.2 times more expensive than graded. The coefficient of substitution in these cases does not exceed 0.8-0.85 and so the gain in production cost from saving metal can be covered by the increase in the price per ton of the substitute steel. A ton of plastic can replace four or five tons of rolled metal. Depending on what kind it is, however, the ton of plastic can cost many times more than carbon steel. Since in substitution processes the effect of a price increase for the substitute material is comparable with a saving achieved by reducing the cost of materials and depends largely on the choice of branch, section and dimensions both of the substitute material and its substituent, a special investigation of the effect of substitution on machine production costs is essential.

Results from such an investigation conducted by S. Kristalnyy for three aggregates for Ministry of Construction, Road and Municipal Machine Building enterprises that are relatively homogenous in terms of output produced are shown in Table 3.

Table 3. Effect of Amount of Metal Used on Output Production Costs in Machine Building.

Group	Number of enterprises	Outlay per ruble of output less wages (kopecks)	Metal used for progressive kinds of rolled metal and metalware (tons per million rubles)	Casting used (tons per million rubles)
	1. Plants by output of excavators			
I	3	60.4	210.1	554.7
II	4	66.8	264.8	469.9
III	6	76.9	136.1	267.7
	2. Plants by production of vehicles			
I	6	66.3	93.2	100.9
II	4	75.8	74.8	231.5
III	6	85.9	64.8	60.6
	3. Plants by production of construction machines			
I	4	52.5	205.3	308.1
II	6	64.4	116.6	399.0
III	4	73.9	104.3	212.3

The effect of the amount of metal used on the production cost of machine building output--outlay per ruble of output less wages--has been analyzed. For this purpose, each aggregate was broken down according to the magnitude of the production cost indicator for the three groups. Outlays per ruble of output increase from the first through the third group, while for the different aggregates the gap in production cost between the extreme groups is about 30-40 percent. It can be seen from Table 3 that for enterprises producing excavators vehicles and construction machines the same pattern is seen: the greater the amount spent per unit of output of progressive kinds of metal output (rolled metal from low-alloy steels, sized metal, curved sections and so forth), the lower the production cost. It is true that the exception is observed for two excavator plants for the group, but this reflects the statistical nature of this pattern. An increase in the specific use of cast iron and steel castings per 1 million rubles of machine building output also makes it possible to reduce production costs. However, here the increased weight of the machine should not be forgotten; for mobile equipment, which road construction equipment is, it not only means an increase in the amount of metal used but also an increase in operating costs, particularly fuel.

Another important source for reducing machine building output production cost is improving the organization of machine building production, particularly on the basis of specialization. Although this question requires further study, figures have been cited in the economics literature according to which the production cost of output at specialized enterprises that manufacture output for intersector use and instruments is lower than at nonspecialized enterprises. Proceeding from evaluations available of despecialization it can be suggested that by eliminating it it is possible to reduce production costs for output in machine building by about 15 percent.

Reducing the production costs for machinery and equipment is also promoted by mechanization of assembly, to which about 30 percent of all labor is devoted in machinery production, while in one-time and short-series production runs it can be 50-60 percent. About 25 percent of machine building has now been mechanized and about 5 percent of assembly work has been automated. The level of mechanization and automation can be substantially raised in the future.

The investigations of A. Varshavskiy and L. Surovina, who used as their example individual kinds of earth-moving and earth-leveling equipment, diesel locomotives, automobiles, tractors and combine harvesters, have shown that up to certain levels the increase in the unit capacity of a machine causes a reduction in the price of unit capacity. However, further increase leads to increased prices per unit of productivity, and this is explained by the reduced production runs for superpowerful equipment, and its design and technologic complexity. Accordingly, substantiating expedient limits for increases in the unit capacity of machines and assemblies is an important precondition for reducing the unit cost of capacity. According to Soviet and foreign investigations, the partial replacement of expensive universal production equipment (for example, lathes) with cheap, narrowly specialized models, particularly if output is organized on the basis of a standardized base model using the modular principle, can promote a reduction in the specific cost of domestic-produced machines. Finally, the development of the production of domestic-produced equipment can reduce imports of expensive foreign equipment.

In the conditions of falling growth rates for capital investments, problems of improving the quality of all investment activity becomes paramount. The most important of these problems is to slow the rate of fall in the capacity equivalent for invested fixed capital and then to stabilize it and increase it. Not only the size of the country's investment potential but also future trends in the capital-output ratio and economic growth rates depend on solving this problem. Taking into account the increasing role of investment potential for the development of the national economy, it is necessary in the near future to accelerate research along this avenue. The USSR Central Statistical Administration should regularly conduct one-time sampling investigations of the relationships between base prices and equipment productivity, improving methodology for conducting such investigations primarily through improving the representative nature of the samples. In the future it would be expedient to organize one-time investigations of the dynamics in the square meter cost of production areas. Economic institutes of the USSR State Committee on Prices, the USSR Academy of Sciences, and the USSR Gosplan, together with sector institutes, should conduct comprehensive research on problems of the capacity equivalent for fixed capital and draw up a system of specific planning measures to reduce outlays and reduce the cost of production in machine building, construction, ferrous metallurgy and the construction materials in industry. Such research will make it possible to raise the level of validity and the normative role of limit prices for designing and planning equipment, buildings and installations, and in the final analysis should promote a slowdown in the rate of fall, the stabilization and growth of the capacity equivalent for fixed capital.

FOOTNOTES

1. VOPROSY EKONOMIKI No 7, 1979, pp 120-132

2. Ibid. No 2, 1977, p 4.

3. "Narodnoye khozyaystvo SSSR v 1978" [The Economy of the USSR in 1978], Statistical Yearbook, "Statistika" Publishing House, 1979 pp 334-336.

4. P.A. Stoun. "Ekonomika i organizatsiya stroitel'stva" [The Economics and Organization of Construction], "Ekonomika" Publishing House, 1979, pp 28-29.

5. VOPROSY EKONOMIKI No 3, 1979, p 28.

6. Ibid. No 3, 1977 p 26.

7. Ibid. No 2, 1975, p 28.

8. N.I. Mityayev. "Osnovnyye proizvodstvennye fondy chernoy metallurgii" [Fixed Production Capital for Ferrous Metallurgy], "Metallurgiya" Publishing House, 1977, p 199.

9. "Kompleksnoye prognozirovaniye nauchno-tekhnicheskogo progressa v oblasti orudiy truda" [Comprehensive Prediction of Scientific and Technical Progress in the Field of Implements of Labor], edited by A.Ye. Varshavskiy. Moscow, Central Institute of Economic Mathematics, 1978, p 175.

10. T.S. Khachaturov. "Effektivnost kapital'nykh vlozheniy" [Effectiveness of Capital Investments], "Ekonomika" Publishing House, 1979, pp 213-214.

11. Energy demand includes demand for electric and mechanical power. Calculated from data on the energy-to-labor and electricity-to-labor ratios for workers and the dynamics of their numerical strength ("Narodnoye khozyaystvo SSSR v 1977 1977," 1978, pp 102, 129).

12. Ya. B. Kvasha and K.B. Leykina. "Fondoyemkost proizvodstva. Metodologicheskiye voprosy" [Production Output-Capital Ratio. Methodological Questions], "Mauka" Publishing House, 1971, pp 5-6.

13. IZVESTIYA AN SSSR. SERIYA EKONOMICHESKAYA, No 5, 1979, p 122.

14. VOPROSY EKONOMIKI No 3, 1977, p 23.

15. Ibid. No 3, 1977 p 26.

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INTRODUCTION OF NEW TECHNOLOGY

METHODOLOGY OF MEASURING COST OF NEW TECHNOLOGY ANALYZED

Efficiency, Unit Cost

Moscow VOPROSY EKONOMIKI in Russian No 9, Sep 80 pp 23-31

[Article by Yu. Tropin]

[Text] The economic indicators of the efficiency of new technology that have been developed and are now being used include the summary indicator of its specific cost per unit productivity or other useful benefit: the ratio of the price to the useful benefit. Admittedly an increase in the unit cost reflects a relative increase in cost and a reduction a relative decrease in the cost of creating the new article as compared with the articles already being produced or some other alternative. But the method of calculating the unit cost and the conclusions framed on that basis are not altogether sound in our view, since by and large the price and the useful benefit are used to determine this indicator. Moreover, the latter is usually examined almost exclusively from the quantitative angle: the number of parts produced, the volume of work accomplished, and so on. Though these are indeed important, they cannot always serve as the basis for a truly general assessment of the level of economic efficiency of machines to be developed, especially in the context of present-day scientific-technical progress, which ensures a constant rise in the technical level and quality of technology.

All improvements to be introduced are related to some degree to the economic efficiency of machines and should be reflected in the summary value indicator of their efficiency--in the unit of the useful benefit. This conforms to those demands which society places upon new technology. "The machines, equipment, instruments and manufacturing processes to be created," it was noted at the 25th CPSU Congress, "must exceed the best domestic and world advances in their technical-and-economic indicators per unit productivity or other useful benefit."

We will first examine the value aspect of the useful benefit. Technology is characterized by the set of performance (technical-and-economic) characteristics, such as productivity, operating life and reliability, service life, level of mechanization and automation, operating time to failure, transportability, etc. The price level and through it the unit cost depends on their specific values. But this is only one important aspect of the economic manifestation of the performance characteristics of machines. Another equally important aspect lies in their impact on the cost of the useful benefit in terms of operating costs (current and capital) to consumers of technology. For instance, labor time to repair trucks exceeds by 30-40-fold the labor intensiveness of their manufacture.[1] The national economy's annual expenditures for major and current repairs of machines and equipment amount to a sizable sum--about 14 billion rubles.[2] The absolute and unit levels of operating costs are also subject to the impact of the relevant technical-and-economic parameters of the machine. That is why an improvement in the quality of technology aimed at increasing its economic efficiency by reducing specific capital and current costs has great importance to the national economy.[3]

We will assess the economic efficiency of a base model, 6668/6B, and a new model, SMZh-166, concrete layer. Their principal technical-and-economic parameters are given in Table 1.

Table 1

	Concrete Placer Models	
	6668/6B	SMZh-166
1. Wholesale price (in rubles)	5,666.0	16,600.0
2. Annual productivity (in cubic meters)	24,300.0	67,300.0
3. Annual current costs to the consumer (in rubles)	5,492.0	9,893.0
4. Service life (in years)	7.0	7.0
5. Unit cost (line 1/line 2; in kopecks per cubic meter)	23.3	24.7
6. Unit current cost (line 3/line 2; in kopecks per cubic meter)	22.6	14.7

It follows from the figures in the table that the new concrete placer, the SMZh-166, is 6 percent ($[(24.7 - 23.3)/23.3] \cdot 100$) more expensive than the base model in terms of specific cost. Does this correspond to the actual state of affairs? It would not seem so. The operating costs of the new concrete placer are 7.9 kopecks per cubic meter lower than those of the base model in terms of unit output. This far exceeds the higher unit cost, which was only 1.4 kopecks per cubic meter. It is important here to take into account that the reduction of unit operating costs has resulted from the new product's performance characteristics.

The analogous computations can be made for any other machines. Differences might arise only in the quantitative values of the indicators. For instance, according to the data of the All-Union Scientific Research Diesel Locomotive Institute, the unit cost of the old narrow-gauge diesel locomotive, the T-46, and the new one, the TU 6A, in terms of unit capacity is

138.9 rubles per horsepower and 131.7 rubles per horsepower, respectively. It was concluded on this basis that the unit cost of capacity was 5.2 percent lower. But it was not taken into account in the computations that the economic efficiency of the new locomotive in absolute and relative values was substantially higher, above all because of the reduction of operating costs. Annual operating costs per unit capacity were 223.9 rubles per horsepower for the base locomotive and 186.2 rubles per horsepower for the new one; that is, they dropped 37.7 rubles per horsepower, or 16.8 percent. So, to have a fuller idea of the economic efficiency of equipment being created, we also need to take operating expenses into account in calculating the cost per unit of the useful benefit. We will refer to this indicator as full unit cost.

In discussing the question of unit cost and full unit cost, we must not overlook a parameter like service life, which determines the product's value and its operating characteristics. This is especially important in the present stage of development of science and technology, whose distinguishing characteristic is a stepping up of rates of obsolescence and renewability of machines which have been put into production. Whereas, for example, at the beginning of the 20th century it took new equipment 35-40 years to become obsolete, in the seventies this time is estimated at 8-9 years for most up-to-date production operations, and in such a progressive industry as the electrical equipment industry, the average product is entirely replaced in 6-8 years. But service life has not been sufficiently reflected in unit cost. Yet it is not possible to get a realistic idea of the level of economic efficiency of products being compared, even if they are equal in their levels of operating costs, if they differ in service life.

It might be supposed on the face of it that problems related to unit cost can be resolved by using the upper price limit. Attempts of this kind have been made in the economics literature, but they have not elucidated the essence of the problem under consideration, but have raised new questions which themselves need to be substantiated.

Imputed costs are the basis of computing the upper price limit. When used to compare different models of equipment, they can be transformed into the following expanded equation:

$$Ts_N Ye_N + Ts_N(1/T_N) + K_N Ye_N + I_N = (P_N/P_B)(Ts_B Ye_N + Ts_B(1/T_B) + K_B Ye_N + I_B), \qquad (1)$$

in which Ts_N and Ts_B are the prices of the new and base models, respectively; T_N and T_B are the operating lives of the new and base products, respectively (taking into account the rate of obsolescence); P_N and P_B are the annual volumes of output (operations) performed per unit of the new and base products, respectively; K_N and K_B are the capital costs which the consumer incurs in using the new and base models, respectively; I_N and I_B are the consumer's current costs in producing the annual volume of output (annual performance of operations) using the new and base models, respectively.

Cost benefits of changing the service life and level of operating costs of the new model as compared to the model being replaced are reflected in the upper price limit. Moreover, the principle of unalterability of the cost per unit of the useful benefit is the basis for forming the Ts_{VP} [upper price limit]; this principle is realized if the wholesale price of the new product is set at the level of its Ts_{VP}. Setting the wholesale price at a level below or above the upper limit must correspondingly reduce or increase the cost per unit of the useful benefit, and that also applies to the full unit cost of new products.

These peculiarities of the upper price limit have been used by a number of economists in determining the unit cost of a new product. Some of them feel that reduction of the specific cost per unit of the useful benefit can be expressed by a cost reduction coefficient, which is calculated by dividing the sales price by the upper price limit of the new product.[4] On the whole this approach furnishes a relative description of the level of economic efficiency of a new product, but it is not indisputable. It is difficult from this coefficient to judge the real unit cost of the new product as compared to the model being compared when the time factor and its dynamic behavior are taken into account. Even though it has been proposed that the level of the benefit for the old product be taken as unity, the problem is still not solved.

Nor is it possible to provide a sound estimate of the level of economic efficiency of a new product from the unit cost calculated by dividing the upper price limit by the size of the useful benefit.[5] V. Gal'perin, who has made the necessary calculations, asserts, for example, that setting a machine's wholesale price at the level Ts_{VP} signifies a rise in its unit cost, and the upper level itself serves as a cover for a rise in the cost of new technology. In our view this is not altogether sound.

There is no question that it is not the upper limit itself that is "guilty" in such conclusions and evaluations. Its practical value and theoretical soundness are well known. It seems that the main reason lies in the fallacy of using the Ts_{VP} to determine the unit cost, since its economic content is not fully taken into account in this operation.

First of all, the upper limit of the price is the maximum economically permissible theoretical value of the wholesale price. It is used to attain in economic terms an equal rate of benefit from using technology per unit of the useful benefit, that is, to state the essential, to achieve equality of the unit costs of all the alternatives being compared (including the base model). Consequently, the Ts_{VP} cannot reflect (through the unit cost) the real dynamic behavior of the economic efficiency of new technology per unit of the useful benefit as compared with the level already attained.

Second, the levels of the unit cost of different versions of new technology which are equally profitable in economic terms, computed on the basis of the Ts_{VP}, may differ from one another, because the level of the upper price limit is directly determined by the values of operating costs and service life of equipment. A small change in them in the new model as compared to the model being replaced or a small difference between the alternatives is sufficient for this to be reflected in the level of the Ts_{VP} and the unit cost calculated from it. Reduction of the level of operating costs and a lengthening of a product's service life will tend to raise the upper price limit and unit cost, and a rise in the level of operating costs or a reduction of the service life will tend to lower them. We will demonstrate this using the figures in Table 2, which presents the technical-and-economic parameters of the new concrete placer, the SMZh-166.[6] As we change its current costs and operating life, we will examine their impact on the level of the upper price limit and the unit cost (see Table 2).

Table 2

	SMZh-166	Alternative Versions 1	2	3	4
1. Annual current costs (in rubles)	9,893.00	9,893.00	9,893.00	8,500.00	11,000.00
2. Annual productivity (in cubic meters)	67,300.00	67,300.00	67,300.00	67,300.00	67,300.00
3. Operating life (in years)	7.00	5.00	9.00	7.00	7.00
4. Upper price limit (in rubles)	33,847.00	28,322.00	37,963.00	38,604.00	30,067.00
5. Unit cost (line 4/line 2; in kopecks per cubic meter)	50.29	42.08	56.41	57.36	44.68

The reduction of current costs and the lengthening of the operating life increased the unit cost from 50.29 kopecks per cubic meter to 57.36 kopecks per cubic meter (version 3) and to 56.41 kopecks per cubic meter (version 2). On the other hand a rise of current costs and reduction of operating life brought about a drop in the unit cost to 44.68 kopecks per cubic meter (version 4) and 42.08 kopecks per cubic meter (version 1). But it would be premature to frame a conclusion on this basis concerning the relative inexpensiveness or expensiveness of the equipment. If the wholesale prices of concrete placers are set at the level Ts_{VP}, they will all be equivalent in economic terms, and their full unit cost ought not to change relative to the model being replaced. The reason for the fluctuation in levels of unit cost of equally beneficial versions lies elsewhere.

The economic consequences of changes in the performance characteristics of the products in relation to the useful benefit are not fully taken into account on the basis of the Ts_{VP}, nor indeed of the wholesale price. Comparability of the equipment with respect to the time factor is not achieved, as can be seen from the figures in Table 2. It is this that brings about the substantial discrepancies in unit values. For the same reason comparison of the sales price of a new product with the Ts_{VP} or comparison of the Ts_{VP} with the lower price limit and again of the Ts_{VP} with the price of the old product[7] can lead to erroneous ideas about a new product's level of economic efficiency.

In our view it is not the upper price limit or wholesale price that is best adopted as the basis for determining the full unit cost of a new product, but rather the imputed costs, or, more accurately, expression (1), in which the initial condition of the economic efficiency of the new product is incorporated: unalterability of cost per unit of the useful benefit. This guarantees comparability of products with respect to service life and a comprehensive value assessment of other technical-and-economic parameters.

For all variations of T_N, K_N and I_N both parts of the expression (1) will be equal, since such fluctuations "pick up" and incorporate the upper price limit ($Ts_{VP} = Ts_N$), which ultimately makes it possible to realize the principle of equal economic profitability of the technology being compared. The full unit costs of the product being replaced (U_{BP}), which are calculated from its imputed costs, are of the initial and upper standard of efficiency of this equal rate of benefit for new models to be developed. They are defined as $U_{BP} = Z_B/P_B$.

For the base concrete layer, the 6668/6B, the value of Z_B will be equal to 7,151 rubles (5,666 x 0.15 + 5,666 · 0.14286 + 5,492). Consequently, the full unit cost is 29.43 kopecks per cubic meter (715,100 kopecks:24,300 cubic meters). It is the value obtained that will be the initial standard of efficiency for the set of new versions of the base machine (U_{NP}), which follows from the equality of imputed costs.

As a matter of fact, the level of imputed costs of the new product is directly proportional to its productivity as compared to the model being replaced. It is sufficient to know the full unit cost of the machine being replaced and the productivity of the new one, Z_N can be determined without complicated computations. For instance, for the SMZh-166 concrete placer, they are 19,806 rubles (29.43 kopecks · 67,300). The result will be the same if we use in the computation the more complicated formula of imputed costs: ($Z_N = Ts_N Ye_N + Ts_N(1/T_N) + K_N Ye_N + I$). When we divide the value found by the productivity, our result is that U_{NP} will be 29.43 kopecks per cubic meter for both this machine and the one being replaced.

If the actual full unit costs of the new product turn out to be higher or lower than the initial standard, then that product will be relatively more expensive or relatively less expensive. In order to ascertain these changes, we need to calculate, first, the actual imputed costs Z_{FN} of the new product, since the values P_N, K_N, I_N and T_N are calculated values, while Ts_N is the economically permissible maximum value. Z_{FN} can be determined from this formula:

$$Z_{FN} = Ts_{OP}Ye_N + Ts_{OP}(1/T_{FN}) + K_{FN}Ye_N + I_{FN}, \qquad (2)$$

in which Ts_{OP}, T_{FN}, K_{FN} and I_{FN} are the wholesale price, actual service life, accompanying capital expenditures and current costs, respectively. Then the full actual unit cost of the new product is calculated thus: $U_{NP} = Z_{FN}/P_N$.

The wholesale price of the new concrete placer, the SMZh-166, is set at the level 16,600 rubles. If the other indicators do not change, its actual imputed costs according to formula (2) will be equal to 14,754 rubles (16,600 x 0.15 + 16,600 x 0.14286 + 9,893), while U_{NP} = 21.92 kopecks per cubic meter (1,475,400 kopecks:67,300 cubic meters) as against the initial standard of 29.43 kopecks per cubic meter. Thus the drop in full unit costs and the relative drop in the cost of the new concrete placer were 25.5 percent (100 - [21.92/29.43] · 100). If the sales price is compared to the upper price limit, the relative drop in cost will be 51 percent (100 - (16,600/33,847) · 100). Taking into account what we have said above, this value is clearly too high.

In our view it is advisable to use the full unit cost as a summary indicator of efficiency in economic substantiation of the production of a new product, in justifying incentives to encourage that production, and so on. This applies above all to the full unit cost of the product being replaced, which can be used as the limit cost standard instead of the ceiling price (Ts_L). Like the ceiling price, they should be examined in the period when the technical assignment for designing the new prototype is being drafted, using this formula:

$$U_{BS} = U_{BP} \cdot \beta, \qquad (3)$$

in which U_{BS} are the adjusted full unit cost of the base model; U_{BP} are the full unit cost of the base product in the year of the computation; and β is the coefficient of reduction (increase) of the unit costs of the base product from the year of computation U_{BP} to the year for whose conditions the wholesale price of the new product is being set.

An important advantage of the full unit costs over the ceiling price as an indicator is its greater accuracy. It is founded on its very basis on actual data, whereas the ceiling price is based on calculated and forecast data. There may be cases, then, when its level is substantially raised (lowered) because of errors in the computations or because of the complexity of fully taking into account the influence of technical-and-economic parameters (which in addition are projected) on the current and capital costs of the design being created.[8] Determining U_{BS} does not necessitate cumbersome computations as are required to find the ceiling price.

It is also necessary to bear in mind that in the process of creating a new product its economic efficiency may be raised by virtue of a reduction of the level of operating costs. But developers are not objectively interested in this kind of reduction, since it tends to increase the Ts_{VP}, which, given the established Ts_L, could make it difficult to fulfill the conditions of the technical assignment for the given parameter (especially for a product that is not efficient enough). They are rather interested in a certain reduction of the economic efficiency of the equipment being developed by virtue of a rise in operating costs, since this reduces the level of the Ts_{VP} from the level previously calculated. This creates for the developers more opportunities for fulfilling the conditions of the contract with respect to the ceiling price. Use of the full unit costs (U_{BS}) as an indicator instead of the Ts_L excludes these adverse manifestations.

Full unit costs are also a sufficiently objective standard for computing the economic benefit to the national economy, both computed (E_R), in connection with the technical-and-economic substantiation of products, and the actual (E), for purposes of setting the wholesale price. First we determine the size of the economic benefit per unit of output using the new product ($E = U_{BP} - U_{NP}$), and then the annual economic benefit ($E_G = E \cdot P_N$) and the benefit over the operating life ($E_N = E_G/[(1/T_{FN}) + Ye_I]$). E_R can be found analogously. But here the unit costs of the new product will be calculated with respect to the projected parameters, and those of the base model from formula (3). The good thing about computing the economic benefit with this method is that the calculation is based on an objective and actual value--the full unit costs of the product being replaced.

Breaking down the full unit costs of the product (the new one and the one to be replaced, the planned and the actual) into the respective components (materials, components, net output, profit, etc.) reveals opportunities to plan them and set limits on them, to discover the real tendencies in the movement of these elements, and also to discover the factors that influence them.

In a majority of production operations the cost of the useful benefit depends on the technical level of machines, equipment and instruments, constant improvement of whose quality is one of the tendencies of scientific-technical progress. K. Marx wrote that the purpose of introducing machines is to "reduce the cost and probably also the price of the commodity, making it cheaper, i.e., reduce the work time required to produce a unit of the commodity."[9]

Reduction of a commodity's cost occurs through a relative drop in the cost of the machine itself, which is reflected in the full unit cost. But a relative cost reduction can also occur by virtue of improvement of manufacturing operations, which largely depends on the machine used. "... The quality of machines and equipment used," K. Marx wrote, "determines whether more or less of the raw material will become waste in the production process."[10]

Much attention is being paid in our country to creation of machines, equipment and instruments that conserve physical and labor resources. For instance, in the production of steel sheet with minus tolerance (11.2 mm x 1,000 mm) instead of the nominal tolerance (12 mm x 1,000 mm) a savings of more than 70 kg of this metal which is in short supply is achieved for every ton of steel. In the 1976-1978 period the savings on raw materials, supplies, fuel and other subjects of labor alone that resulted from these measures was about 8 billion rubles. But this potential has not been exhausted by any means. The coefficient of utilization of metal in machine-building, rolled steel products, etc., is still low.

But improvement of the quality parameters of machines ordinarily requires additional funds. In particular, to increase the precision class of castings (other conditions being equal) additional expenditures are required to improve metal forms, and this increases their full unit costs. It turns out that the higher the quality of a new product, the more expensive it will be in relative terms. But when the improved form is used in casting, one can obtain castings with a higher class of precision, and subsequently smaller expenditures of live and embodied labor are required in machining them to the set standard. There is also a saving of metal here. Consequently, from the standpoint of the ultimate result, that is, the useful benefit, there is no ambiguity here.

The economic benefit, which depends upon the performance characteristics of machines, is not fully taken into account at present in the imputed costs, the unit price and the system of economic incentives. New technology is recognized to be efficient if the ratio of the economic benefit to the wholesale price is 15 percent or higher. In this case it is economically advantageous for the manufacturing enterprise to produce the new product. From the proceeds of its sale it will reimburse production costs and will obtain an incentive supplement applied to the wholesale price in the form of additional profit. A system for economic stimulation of enterprises acting as developers and consumers of the particular product has been worked out and is in effect. Consequently, such an important line of efficiency as the quality of machines is unjustifiably left out of this system.

The question of the need to give fuller consideration to quality parameters (related to the benefit, the saving on physical and labor resources) in technical-and-economic substantiation, development and material incentives pertaining to new products has been repeatedly raised in the pages of this journal.[11] Pursuit of this direction for increasing the efficiency of social production is conducive to orienting current and multiannual (5-year and longer-range) plans of scientific-technical progress toward systems of machines and improvement of their quality; toward development of pace-setting standards; toward use of the program method of planning production and improving the product on the basis of its full life cycle. Important opportunities are embodied in the extension of the system of certification to technical developments, designs and technical specifications.

In recent years a number of documents on methods have been drafted which reflect certain indicators "product quality--quality of the useful benefit." They include, for example, the Instruction on Procedure for Coordinated Development, Approval and Application of Technical Specifications and Prices to Products of Machinebuilding for Industrial and Technical Purposes, the Method (Basic Principles) of Determining the Economic Efficiency of Using New Technology, Inventions and Production Innovations in the National Economy, etc. Work is being done to improve them further. Experience has been gained in determining volumes of output in standard units that reflect quality parameters and performance characteristics of products, supplies and raw materials. Thus the methodological base is taking shape for computing the economic results of improvement of the quality of machines.

The full unit costs of the quality of products (in the breakdown we have used) can be taken into account on the basis of summary imputed costs.[12] Then the initial equation (1) for determining the full unit costs will take the following form:

$$Z_N + Z_{N1} + Z_{N2} = (P_N/P_B)(Z_B + Z_{B1} + Z_{B2}), \quad (4)$$

in which Z_N and Z_B are the imputed costs of the new and base technology, respectively; Z_{N1} and Z_{B1} are the imputed costs of the quality of the product and of the other useful benefits attained in using the new and base technology, respectively; Z_{N2} and Z_{B2} are the imputed costs pertaining to social parameters. When there is a change in the level of Z_{N1} and Z_{N2} from their values for the base product, we need to make corresponding adjustments in the formulas for calculation of the full unit cost. But it is advisable to single out their specific values in the standard U_N and U_B and to take them into account separately.

The decree of the CPSU Central Committee and USSR Council of Ministers entitled "On Improving Planning and Strengthening the Influence of the Economic Mechanism on Increasing Production Efficiency and Work Quality" has given a central place to further improvement of organizational and economic measures aimed at developing and speeding up industrial application of advances of scientific-technical progress. Performance of these measures depends largely on improving methods of calculating the indicators for determining the economic efficiency of new technology. The use of the proposed indicators in planning and stimulating the production of new technology will in our view contribute to the soundness of the economic decisions made.

FOOTNOTES

1. V. Deryabin, "Forecasting the Economic Results of Improving Machines in the Predesign Stage," VOPROSY EKONOMIKI, No 8, 1979, p 132.

2. B. K. Zlobin, "Ekonomicheskiy mekhanizm povysheniya kachestva produktsii" [Economic Mechanism for Increasing Product Quality], Izdatel'stvo "Mysl'," 1980, p 95.

3. A reduction of the level of operating costs may be related to a certain rise in the specific cost of technology, and vice versa, since these indicators are closely interrelated. For example, over the last 20 years the saving on operating costs in rail transport resulting from application of new forms of traction have been 83-85 billion rubles. But on the whole the benefit from this introduction has been only about 30 billion rubles (see "Methods and Practice of Determining the Efficiency of Capital Investments and New Technology," "Sbornik nauchnoy informatsii" [Anthology of Scientific Information], Issue 30, Izdatel'stvo "Nauka," 1979, p 94).

4. See, for example, A. Koshuta and L. Rozenova, "Functions of Prices in the Context of Scientific-Technical Progress," VOPROSY EKONOMIKI, No 3, 1977, pp 25-26.

5. V. Gal'perin, "Efficiency and Prices of New Technology," VOPROSY EKONOMIKI, No 3, 1977, p 13; G. Kulagin, "Economic Criteria for Applying New Technology," VOPROSY EKONOMIKI, No 9, 1979, pp 112-113.

6. All calculations hereafter for the new product and product being replaced will be made without taking into account the accompanying capital costs, whose levels are equal.

7. L. Shevchenko, "Efficiency, Price and Obsolescence of Technology," VOPROSY EKONOMIKI, No 6, 1979, p 25.

8. The complexity of reliably determining the level of costs and the economic benefit of new technology in the stage of its development has been noted by many economists (for example, V. Fel'zenbaum, "Determination of the Planned Benefit of New Technology," VOPROSY EKONOMIKI, No 1, 1978, p 116; R. Fatkhutdinov, "Economic Substantiation of Increasing the quality of Products," VOPROSY EKONOMIKI, No 3, 1978, p 109, etc.).

9. K. Marx and F. Engels, "Sochineniya" [Works], Vol 47, p 351.

10. K. Marx and F. Engels, "Sochineniya," Vol 25, Part I, p 114.

11. See, for example, V. Astaf'yev, "Managing Scientific-Technical Progress in the Industry," VOPROSY EKONOMIKI, No 2, 1978, p 100; L. Gatovskiy, "Speeding Up Scientific-Technical Progress and Increasing Its Efficiency," VOPROSY EKONOMIKI, No 6, 1978, p 122; V. Ivanchenko, "Criterion of Efficiency and Quality," VOPROSY EKONOMIKI, No 7, 1978, pp 37, 43; D. Palterovich, "Technical Progress and Planning the Composition of the Implements of Labor," VOPROSY EKONOMIKI, No 2, 1979, p 44.

12. L. Gatovskiy, "Socioeconomic Efficiency of New Technology," VOPROSY EKONOMIKI, No 2, 1979, p 61; A. Konson, "Efficiency of Qualitatively New Technology," VOPROSY EKONOMIKI, No 2, 1979, p 55.

Economic Efficiency of Technology

Moscow VOPROSY EKONOMIKI in Russian No 9, Sep 80 pp 119-128

[Article by N. Miloslavskiy]

[Text] The decree of the CPSU Central Committee and USSR Council of Ministers on improving planning and further improvement of the economic mechanism attributes great importance to estimation of the anticipated and actual economic benefit to the national economy from utilizing the advances of science and technology.

At the same time a substantial role in increasing the efficiency of social production is to be played by assigning to industrial ministries, associations and enterprises in plans of economic and social development targets for the growth of net output (normative) and for the rise of labor productivity measured in terms of net output. Adoption of these indicators in the practice of planning and cost accounting (khozraschet) will be regulated by new methods guidelines.

Methods and instructions adopted in various years on determination of the economic efficiency of new technology and capital investments, on price setting and on economic incentives to stimulate scientific-technical progress in physical production are simultaneously in effect in the country at the present time. It is by these documents that one is supposed to be guided in the stages of planning new technology, scientific development, project planning, and organization of industrial production, and this moreover is to be done in the context of cost accounting at all levels of management. But if one compares them, one finds that they are not sufficiently consistent, and a number of the basic premises are even contradictory.

We will illustrate what we have said by taking the examples of the Standard Method of Determining the Economic Efficiency of Capital Investments (approved in 1969 by USSR Gosplan, USSR Gosstroy and the USSR Academy of Sciences); the Method of Determining Wholesale Prices of New Products for Industrial and Technical Purposes (approved by the USSR State Committee for Prices in agreement with the State Committee for Science and Technology in 1974); the Method (Basic Principles) of Determining the Economic Efficiency of Using New Technology, Inventions and Production Innovations in the National Economy (approved in 1977 by the State Committee for Science and

Technology, USSR Gosplan, the USSR Academy of Sciences and the State Committee for Inventions).*

For instance, the standard coefficient of efficiency of capital investments Ye_N, according to the Gosplan Method, is set at a level of at least 0.12, while under the GKNT Method it is 0.15. Moreover, in the first case deviations from the standard coefficient are allowed in industrywide instructions, but in the latter it is adopted as the sole standard, and deviations are not permitted.

The coefficient for prorating outlays made at different times, which is the same in the conditions of its application, is adopted at 0.08 in the Gosplan Method and 0.10 in the GKNT Method. The initial discrepancy of 20 percent rises sharply in computations pertaining to complicated percentages over prolonged periods amounting to many years. Yet either of these values can be adopted in any region of the country and in any institution at the discretion of the persons using this or that method.

A still larger difference between the two methods is manifested on the fundamental question of the procedure for quantitative computation of the efficiency of new technology. For example, one and the same means of production--a machine--is examined in the Gosplan Method from the standpoint of the benefit over 1 year of its operation (the gain in terms of imputed costs), while in the GKNT Method it is regarded over a concrete service life given in advance.

The Goskomtsen Method establishes the same method as the GKNT Method for computing the economic benefit from utilizing new technology over its service life, and they also coincide in the structures of the computational formulas, but certain of the principal elements in these formulas differ fundamentally, specifically: instead of the imputed costs of production of the base machine (being replaced) and the new implement the Goskomtsen Method takes the price and the lower price limit, respectively, of these machines, that is, standards of profitability differentiated by industries and subindustries are introduced; in some cases they are computed relative to the value of productive capital, and in others relative to the production cost; instead of partially taking into account the consumer's capital investments accompanying application of the new technology with the descending coefficient

$$Ye_N/(P_2 + Ye_N),$$

in the Goskomtsen Method its full value has to be taken into account, and that is approximately twice as great.

* Hereafter these documents will be referred to briefly as follows: the Gosplan Method, the Goskomtsen [State Committee for Prices] Method and the GKNT [State Committee for Science and Technology] Method, respectively.

What we have said above indicates the need to create and establish throughout the country uniform foundations for determining the economic efficiency of new technology, capital investments, price setting and economic incentives of scientific-technical progress. The partial method used for special purposes should be renewed and coordinated on the basis of this fundamental document.

1. In accordance with the Method of Determining the Economic Efficiency of Using New Technology, Inventions and Production Innovations in the National Economy (hereafter briefly referred to as the Method), the principal indicator of the efficiency of new technology (inventions and production innovations) from the standpoint of the national economy is the indicator of the annual economic benefit, which depending on the type of new technology is to be calculated either from the formula of the difference in imputed costs (3),* or according to three computational formulas (4), (5) and (7), introduced for the first time by the Method. We should point out in this connection that the annual economic benefit of new technology should be determined by comparing the imputed costs for the base technology (the one being replaced) and the new technology and that in the final analysis it is expressed in a growth of the national income.

The question arises: Does this expand opportunities for computing the economic efficiency of new technology? We will examine the conclusion and structure of new formulas as compared to formula (3) adopted in the instructions previously in effect; according to the notation used in the Method, it takes the form:**

$$E = (Z_1 - Z_2)A_2, \qquad (3)$$

in which Z_1 and Z_2 are imputed costs of production per unit output (work) performed by means of the technology being replaced and the new technology, respectively; A_2 is the annual volume of production (performance of work) by means of the new technology in physical units. In this $Z_1 = S_1 + Ye_NK_1$; $Z_2 = S_2 + Ye_NK_2$, in which S_1 and S_2 are the production cost per unit output (work); K_1 and K_2 are specific capital investments in productive capital; Ye_N is the standard coefficient of efficiency of capital investments, which is equal to 0.15.

Computation using the formula (3) is allowed by the Method only in case of application of new manufacturing processes, mechanization and automation of production, and methods of organizing production and work which afford a saving on production resources for one and the same output.

* The numbering of the Method's formulas is retained here and hereafter. New expressions introduced are denoted by indexing the numbers this way: 1", 2", 3", and so on.

** Here and hereafter the lower indices (1, 2) pertain respectively to the computational elements of the base version (being replaced) and the new version of the technology and manufacturing process.

In all other cases, and specifically in the production and use of new means of labor (machines, equipment and instruments), new subjects of labor (supplies, raw materials and fuel) and a new product for nonproductive purposes (or one of improved quality), the annual economic benefit is to be computed according to the new formulas we have mentioned.

The new formulas of the Method can be derived from the general condition of the growth of net profit of enterprises under the respective specific suppositions for each of the three cases of computation indicated:

$$E = [(Ts_{V_2} - Z_2) - a\gamma(Ts_1 - Z_1)]A_2, \qquad (1'')$$

in which Ts_1 is the price of the base technology; Ts_{V_2} is the upper price limit of the new technology; a is the ratio of the productivity of the new machine to that of the machine being replaced or unit costs of the machine being replaced and the new machine (in the notation adopted in the Method: V_2/V_1 and U_1/U_2, respectively); $\gamma = (R_1 + Ye_N)/(R_2 + Ye_N)$ is the corrective coefficient for taking into account differences in service life between the base ($t_1 = 1/R_1$) and new ($t_2 = 1/R_2$) equipment.

The upper price limit of the new technology is determined from the condition of equality of imputed costs for the versions being compared in the sphere where the technology is to be applied.

As a matter of fact, after substituting the values of these parameters into the initial condition of a growth of net output (1"), we get formula (4) of the method for computing the annual economic benefit from production and use of new durable instruments of labor with improved quality characteristics (with respect to productivity and the like) with abbreviated notation:

$$E = [aZ_1([R_1 + Ye_N]/[R_2 + Ye_N]) + ([\Delta I^1 - Ye_N\Delta K^1]/[R_2 + Ye_N]) - Z_2]A_2, \qquad (4)$$

in which ΔI^1 is the annual saving in the sphere of use of the technology on the basis of operating costs with the exception of outlays for full replacement of the base technology in the new technology relative to the total volume of output produced per unit of the new technology; ΔK^1 is the saving corresponding to these costs in accompanying capital investments in the sphere of use of the technology; A_2 is the annual volume of output of the new technology in physical units.

If we substitute into formula (1") the coefficients of full replacement $R_1 = R_2 = 1$, apply the increments ΔI^1 and ΔK^1 not to the entire volume of output, but to the unit output produced using the new instrument of labor, and correspondingly determine the upper price limit, then we get formula (5) of the Method for determining the annual economic benefit from the production and use of new or improved subjects of labor and also of instruments of labor with a service life less than 1 year.

Finally, substituting into formula (1") $Ts_{V_2} = S + P$ and $Ts_1 = Z_1 = 0$, in which P is the profit from the sales per unit of a product for nonproductive purposes, we get formula (7) for computation of the annual economic benefit from production of a new product to meet the needs of the public:

$$E = (P - Ye_N K)A_2. \tag{7}$$

We analogously obtain the formula of the annual economic benefit from production of an improved product:

$$E = [(P_2 - Ye_N K_2) - (P_1 - Ye_N K_1)]A_2. \tag{7a}$$

Returning to the initial formula of the growth of net profit (1"), we must note that its structural elements diverge from the idea of the basic formula (3) concerning computation of the standard efficiency Ye_N in portions of capital investments or the value of productive capital. After the common denominator $(R_2 + Ye_N)$ has been dispensed with, "reductions of reductions" of the type $Ye_N Z$ immediately appear, whereas by the logic of the method of imputed costs, in our opinion, products only of the type $Ye_N K$ or $Ye_N Ts$ are possible here. This is obviously a consequence of the treatment of the economic benefit adopted by the Method, which calls for equating the annual output (operation) only in the sphere of application of the equipment, but does not take into account that by the very nature of the problem this kind of identity does not exist in the sphere of its production. We will examine the argument we have expressed in more detail.

We will make the formula of the growth of net profit (1") relative to the unit of the new technology ($A_2 = 1$) and bring it to the following form:

$$E = (aZ_1 - Z_2) + aZ_1([R_1 - R_2]/[R_2 + Ye_N]) + (Ts_{V_2} - a\gamma Ts_1). \tag{2"}$$

In this case the difference $(aZ_1 - Z_2)$ can be regarded as the economic benefit in the sphere of production of the new technology and the base technology only if output is the same in the year covered by the computation, that is, if the sum of the two last terms on the right side reflects the economic benefit in the sphere of application that is independent of the economic peculiarities of the new and base technology. But the conditions of the problem envisage the opposite case, when the difference in service life and in the size of accompanying costs I^1 and K^1 is determined by the physical and technical characteristics of the new and base technology, imparted to them when they were created.

Even when $(Ts_{V_2} - a\gamma Ts_1) = (\Delta I^1 + Ye_N \Delta K^1)/(R_2 + Ye_N) = 0$, the sum of the first two terms on the right side cannot be regarded as the difference of imputed costs incurred in the year covered by the calculation for the new and base versions of the production of the equipment. On the contrary, this assertion amounts to an artificial supposition that it is enough to increase the imputed costs aZ_1 for the base version by the magnitude $aZ_1 = (R_1 - R_2)/(R_2 + Ye_N)$ to ensure output in the accounting year of products possessing the quality characteristics of the unit of new technology. An assumption of this kind does not follow from the conditions of the problem. In other words, a certain third version is being introduced into the calculation and it is with this (and by no means with the base version) that use of the new technology is being compared. For instance, if the new and base technology are characterized by the same productivity (N units of output per year) and differ only in service life (say, $t_1 = 5$ years and $t_2 = 10$ years), then $E = Z_1([0.2 - 0.1]/[0.1 + 0.15]) + Z_1 - Z_2 = 1.4\ Z_1 - Z_2$.

But it does not follow from this example that by increasing the imputed costs by a factor of 1.4 we can thereby (by virtue of the third version) eliminate the difference in service life of the new and base technology.

This erroneous use of the method of imputed costs ultimately gives rise to a contradiction between the condition of the growth of net profit (1") and the basic formula (3). The reason is that one and the same type of implement or subject of labor is first (so long as it is considered new) compared with the base technology with respect to their imputed costs of manufacture according to formula (1"), but later (when the technology for use of the equipment is being updated) this is done with respect to the cost of their manufacture in accordance with (3).

On the basis of what we have said above, we can draw the conclusion that it would be more advisable to evaluate the computed benefit from production and use per unit of the new technology in the form of the growth of the actual rather than the net profit and determine it in the form of the algebraic sum of changes in the value of the technology as compared with the base technology by virtue of the new technology for production of equipment and the consumer's utilization of the improved quality characteristics of the new technology over its service life.

We will denote the value per unit of the new and base technology, which reflects the socially necessary expenditures of labor to produce them, as Ts_1 and Ts_2, respectively; then this algebraic sum takes this form:

$$E = (aTs_1 - Ts_2) + aTs_1([R_1 - R_2]/[R_2 + Ye_N]) + (Ts_{V_2} - a\gamma Ts_1). \qquad (2a")$$

A comparison of the formulas (2") and (2a") shows that the value of the product (Ts_1, Ts_2) is being equated with the imputed costs of its manufacture (Z_1, Z_2). After all, the method of imputed costs is based on applying one and the same efficiency coefficient Ye_N not to the basic capital investments, but only to supplemental capital investments, when the alternative to their use in any industry of physical production is one and the same method of using them for the national economy as a whole. The coefficient Ye_N is legitimately used in such computations as the sole indicator of relations between the elements of the balance of income, expenditures and the value of productive capital. This coefficient is relatively stable even in time, since with a growth of the national income the absolute sum of funds allocated to the consumption fund also increases.

By contrast with Ye_N, the industrywide coefficients of profitability Ye_0 are computed with respect to the total amount of capital investments (and not the additional amount), which is the value of productive capital, and that is why they can be used to determine the transformed form of the value of the surplus product created in industries. Taking them in computations as the same for different production industries is to fail to take into account the influence of differences in the level of the equipment-worker ratio.

Formula (7) can be reduced to the form: $(Tsv_2 - Z_2)$, and formula (7a) to the form: $(aZ_1 - Z_2) + (Tsv_2 - Ts_1)$, which indicates, in our opinion, not only a confusion of the concepts of the value of the product (Ts_1, Ts_2) with the imputed costs of its manufacture (Z_1, Z_2), but also other indeterminacy with respect to the procedure for computing the upper price limit Tsv_2.

The accompanying capital investments K^1 to create the productive capital and the operating costs I^1 must be taken into account under the Methodological Guidelines for Compilation of State Plans of Development of the USSR National Economy and the Basic Principles for Planning, Recording and Calculating the Production Cost of Industrial Products. But this means that K^1 and I^1 are basically determined from the value (in actuality from the prices) of their component elements, while the analogous indicators for the base and new technology are determined from the imputed costs of their manufacture. In this procedure the size of the surplus product is reflected in the values K^1 and I^1 by means of the profitability coefficient Ye_0, which, as we know, varies in practice, though not in theory, from industry to industry in the range from fractions of a percentage point to tens of percentage points, while in the formula of imputed costs $(S + Ye_NK)$ the coefficient Ye_N must be taken at the invariable level of 15 percent in accordance with the Method.

Thus we either have to give up the double counting of the annual economic benefit from production and use of new implements and subjects of labor which has been introduced by the Method, or first conduct a reform of price setting (set prices equal to imputed costs) and only then put the new Method into effect.

2. It is well known that the economic benefit from application of new technology and manufacturing processes can be computed either directly in the form of the difference between imputed costs

$$\Delta Z = Z_1 - Z_2 = \Delta S + Ye_N \Delta K, \qquad (3'')$$

or by capitalizing it, that is, by taking it for the accounting (first) year of the innovation's application in this form:

$$\Delta\overline{K} = (\Delta Z/Ye_N) = \Delta K + (\Delta S/Ye_N). \qquad (4'')$$

The quantity $\Delta\overline{K}$ can be regarded as the full saving of socially necessary (abstract) capital investments.

From the computations of the main formula (4) of those newly introduced by the Method--the formula of the annual economic benefit from production and use of new implements of labor--we obtain a far larger benefit than with (3") and far smaller than with (4"), even if we do not take into account differences between the value of the implements of labor and the imputed costs of their manufacture. For instance, when the service life of an implement of labor is $t = 10$, the annual economic benefit obtained is fourfold greater than when calculated from formula (3") and 1.67-fold smaller than from formula (4").

We will examine this question in more detail on the basis of the generalized formula of the saving on capital investments over any period of application t_j of any length (so long as it is longer than the service life) of a technical innovation so as to take into account the simple or compound interest on capital outlays.

In the first case the generalized formula is introduced under the following conditions: settlement (repayment) of the capitalized amount $\Delta\overline{K}_j$ in equal installments over the period t_j; annual charge of simple interest on ΔK_j at the rate of $Ye_N \cdot 100$. Applying the condition of equality of imputed costs and setting $R_j = 1/t_j$, we can write:

$$\Delta\overline{K}_j = \Delta\overline{Z}\rho/(R_j + Ye_N). \qquad (5'')$$

As the length of the period covered by the computation increases, the parameter $R_j \to 0$, and at the limit formula (5") passes over into formula (4"). At the intermediate values $1 > R_j > 0$ formula (5") expresses the capitalized benefit over the anticipated period of use of the technical innovation, including a new production process.

In the second case the generalized formula of the saving on capital investments is introduced under the following conditions: successive application of the capital investments K_i at the time intervals t_i over the entire period of application of the technology $t_j = n_i t_i$; augmentation by $Ye \cdot 100$ percent of the calculated value of the quantity K_i over t_i years according to the formula of compound interest on capital outlays:

$K_t = K_i(1 + Ye)^{t-1}$.

The sum of capital investments assigned to the first year K_i over the period t_j is determined as the sum of the terms of a geometric progression whose first term is K_i, whose common ratio is $q = 1/(1 + Ye)^{t_i}$ and the number of whose terms is n_i:

$$\overline{K} = \sum_{\psi=1}^{\psi=n_i-1} K_i/(1 + Ye)^{\psi(t_i-1)}. \qquad (6'')$$

From the formula for the sum of a series of this kind we get:

$$\overline{K}_i = K_i([q^{n_i t_i} - 1]/[q^{t_i} - 1]) = K_i([(1 + Ye)^{n_i t_i} - 1]/[(1 + Ye)^{n_i t_i}]) : [(1 + Ye)^{t_i} - 1]/(1 + Ye)^{t_i}. \qquad (7'')$$

If we now introduce the parameter proposed by the Soviet scientist Lur'ye:

$$\rho_t = Ye/([1 + Ye]^t - 1), \qquad (8'')$$

then the formula for reducing a successive series of capital investments K_i over the period t_j to the first year takes the following simplified form:

$$\overline{K}_j = K_i([\rho_{t_i} + Ye]/[\rho_{n_i t_i} + Ye]). \qquad (9'')$$

The generalized formula of the saving on capital investments by virtue of use of new technology with the value Ts_2 over the period $t_j = n_1 t_1 = n_2 t_2$ instead of a units of the base technology with a total value aTs_1 can also be formed by means of formula (9"). Moreover, for direct operating costs I^1 in the technology's sphere of application we need to take $\rho_1 = 1$ in connection with the value $t = 1$, and for accompanying capital investments we take the value of ρ_1 on the basis of the specific replacement periods for each of them and the number of terms in the series for the condition $t_j = n_1 t_j$.

As a result the formula of the saving on capital investments at compound interest can be written analogously to (5") in the following form:

$$\Delta\overline{K}_j = \Delta\overline{Z}_\rho/(\rho_j + Ye) = (aTs_1[\rho_1 + Ye] + \Delta I^1[1 + Ye] + \Sigma_1 K^1{}_1[\rho_1 + Ye] - \Sigma_2 K^1{}_2[\rho'' + Ye] - Ts_2[\rho_2 + Ye])/(\rho_j + Ye). \qquad (10'')$$

Here the sums Σ_1 and Σ_2 pertain to the accompanying capital investments in application of the new and base technology, respectively. The formulas (5") and (10") for calculation at simple or compound interest with corresponding value of the numerator can be expressed by a single summary formula of the saving on capital investments:

$$\delta\overline{K}_j = \delta\overline{Z}/(R_\delta + Ye_\delta). \qquad (11'')$$

The summary formula (11") of the saving on capital investments $\delta\overline{K}_j$ in the modifications indicated (5") and (10") is a characteristic of capitalization (reduced to the first year) of regular one-time and current outlays over the period to come. It can characterize the benefit from application not only of new implements and subjects of labor, but also of a new manufacturing process for various practical purposes of economic planning, project planning, price setting and stimulation of scientific-technical progress. This means that the quantity $\delta\overline{K}_j$ can be taken into account in the form of the characteristics noted above.

a) At $R_j = \rho_j = 0$ (that is, at $t_j \to \infty$)--as a criterion of the efficiency of the new technology and manufacturing process, since their impact on the economic efficiency of production is not restricted to the period in which the specific unit of the means of labor operates. On the contrary, as we know, any implement of labor, once it is created and applied, takes on the character of a beneficial force of nature, since it can be continuously reproduced thereafter. The same applies to any other type of technical innovation which society adopts to equip physical production. We are thus talking about the economic benefit of raising the technical level of manufacturing processes as a constantly operative factor influencing the dynamics of the national income. This does not mean that in actuality there will be only a simple reproduction of the new technology, but the benefit from future application of its newer forms must be calculated from the level obtained by the new technology under consideration.

The method of capitalization of imputed costs which was used in forming the modifications (5") and (10") of the summary formula makes it possible to state additional arguments concerning the relationship between the coefficients Ye and Ye_N. To be specific, the question arises: Are they identical or different? The Method offers what we believe to be the correct instruction of taking $Ye < Ye_N$. But the opinions of various authors continue to differ.

Yet a condition of the correct relationship between Ye_N and Ye is the requirement of the equality of the sum of capital investments over the period $t_j \to \infty$ reduced to the first year regardless of the method of reduction--using simple or compound interest. This equality is a legitimate requirement so long as the quantities K_i and the intervals t_i are taken as absolutely identical in both methods of computation and are written as follows:

$$K_i([R_i + Ye_N]/[R_j + Ye_N]) \to K_i([\rho_i + Ye]/[\rho_j + Ye]), \text{ if } t_j \to \infty.$$

At the limit, then, this equality must hold: $(R_i + Ye_N)/Ye_N = (\rho_i + Ye)/Ye$, and consequently $Ye/Ye_N = \rho_i/R_i$.

The parameter ρ_i, as Lur'ye established, shows what portion of K_i must annually be charged to the replacement fund if these deductions are to be used on the basis of compound interest to accumulate (repay) the sum K_i by the end of the period t_i. Which means that $\rho_i < R_i = 1/t_i$, and the standard used for conversion of capital investments made at different times Ye should be taken in economic calculations lower than the standard efficiency coefficient of capital investments Ye_N.

b) At $R_j = R_2$ (or $\rho_j = \rho_2$)--the quantity δK_2 is the addition ΔTs_2 to the cost of production of the new implement of labor, whose dimensionality is that of the price, since it follows from the structure of the summary formula that this addition is repaid over the service life of the implement of labor $t_2 = 1/R_2$ and charges at the rates Ye_N or Ye are annually made for it.

We believe that formula (4) of the Method, under the assumption indicated above of the equality of Z = Ts, is a special case of application of formula (5"), and consequently, the annual economic benefit determined with it also has the dimensionality of the price.

Yet it is well known that a change in the price (estimated cost) of means of production for manufacturing purposes, just like a change in the production cost of the product manufactured with them, cannot in and of themselves serve as a criterion of the economic efficiency of new technology. We should take into account both these factors in the form of the change of the imputed costs (3") or the abstract capital investments (4").

The Method envisages that as the calculations are made more precise, the parameters R_1 and R_2 in the formula (4) are to be taken from the data of Appendix 2, that is, are to be replaced by ρ_1 and ρ_2 from formula (8").

But on the basis of formula (10"), when $t_j = t_2$, we become convinced that even in the special case when there is a change only in the service life of the technology, in addition to replacement of the parameters R by ρ, there must at the same time be a substitution of the rate of reduction of outlays at different times Ye = 0.1 for the rate of efficiency of capital investments $Ye_N = 0.15$.

In the more general case when the accompanying outlays are also changing, the error as compared to formula (10") increases still more, and thus formal substitution of the parameters R_1 and R_2 does not at all signify that one has thereby made the results of the computation more precise. Even when $Ye_N = Ye$, which even the Method itself does not allow, it does not follow that one should determine the sum of replacement deductions for the new and base technology at compound interest, and those for other jointly used (accompanying) machines--at simple interest.

c) At $0 < \rho_j < \rho_2$ (or $0 < \rho_j < \rho_2$) [sic]--the value $\delta \bar{K}_j$ can be taken into account (for example, to encourage applied scientific research) as an estimate of the capitalized benefit from application of the new technology over the forecast period of its use (operation) $tp = 1/Tp$, if it is longer than

1 year (for a new process and subjects of labor) or exceeds the physical service life of equipment (for new machines--motors that wear out rapidly, for example).

3. For economic substantiation of a unified technical policy on the scale of the national economy, for commensurate remuneration of enterprises, scientific-production associations and inventors for creation and application of new technology, and also for correct estimation of the actual dynamics of the national income, it would be advisable if in the system of the USSR Central Statistical Administration the formulas for determining the efficiency oi various types of new technology and manufacturing processes were economically compatible. An analysis of the summary formula of the economy on capital investments (11") shows that calculations based on the index of the annual economic benefit do not meet this requirement.

It can be shown by the simplest substitutions that if the annual economic benefit from use of implements of labor in one industry even exceeds the size of the benefit from application of new subjects of labor or manufacturing processes in other industries, it still by no means follows that the first of these directions of technical progress and utilization of capital investments is preferable. After all, in this version the economic gain is estimated over a number of years of the new technology's application, while in the other cases it is estimated over only 1 year. The indicators of the benefit from use of implements of labor themselves are also incompatible when their service life differs.

Nor is a unity of approach assured in evaluating the economic contribution of enterprises creating new technology. As a matter of fact, cases are possible when an increase in the service life of equipment is by no means a merit of the enterprise or scientific-production association, but is attained only by applying a more durable material in the construction. Nevertheless the initial indicator for assigning the award on the basis of the annual benefit increases in accordance with the length of the service life of the instruments of labor.

In statistical records of the actual growth of the national income in a given year as compared to previous years, a distorted picture may be obtained on the basis of the sum of increments of annual economic benefits, since the benefit from application of new machines has already been recorded in advance over a number of years. To sum up the annual economic benefits in reports for the given year in the industry or the national economy as a whole means summing up figures which pertain to different accounting periods.

In connection with what we have said the indicators of the annual economic benefit pertaining to the production of new machines, equipment, instruments and other forms of durable new technology are not in our opinion identical to economically compatible indicators of the actual efficiency of new technology, which should be evaluated on the basis of the final result in the sphere of application. At the same time it is high time to make the transition from economic computations on the basis of simplified imputed costs as a function of only two factors (production cost and specific capital investments) to use of the multifactor formula of imputed costs by making changes in production cost commensurable with the growth not only of capital investments, but also labor expenditures and expenditure of the most important types of natural resources.

It seems to us advisable for the remarks we have made and the theoretical considerations related to them to be taken into account in drafting the principles for determining the economic efficiency of new technology, capital investments and price setting.

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